ADRE® for Windows and full spectrum plots

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Bob Shannon recently received the following question from one of our customers. His answer explains how to get more value from your ADRE® for Windows (Automated Diagnostics for Rotating Equipment) by recognizing the relationship between plots and the many variables that affect their accuracy and content. For more information on full spectrum, please see the article on page 17.

Q I have a question about a **full spectrum plot** I generated with ADRE® for Windows software. Bently Nevada literature (**Orbit** June 1998, Vol.19, No.2) clearly states that the sum of the forward and reverse vibration components is the length of the major axis of the orbit, and the difference is the minor axis. My plots don't agree with this. See my enclosed plots (Figures 1, 2, and 3). They are close, and the ratio of (FWD+REV) / (FWD-REV) is the same as the ratio of the orbit, so the degree of ellipticity is represented; but the numbers don't make sense. The only thought I had was that the orbit needed to be slow-roll compensated, but that also did not help. The machine is a centrifugal compressor which rotates at 31,800 rpm. The data was acquired with 1000 Hz frequency span and averaged during steady state operating conditions. Could you take a look at the enclosed plots and let me know what is wrong?

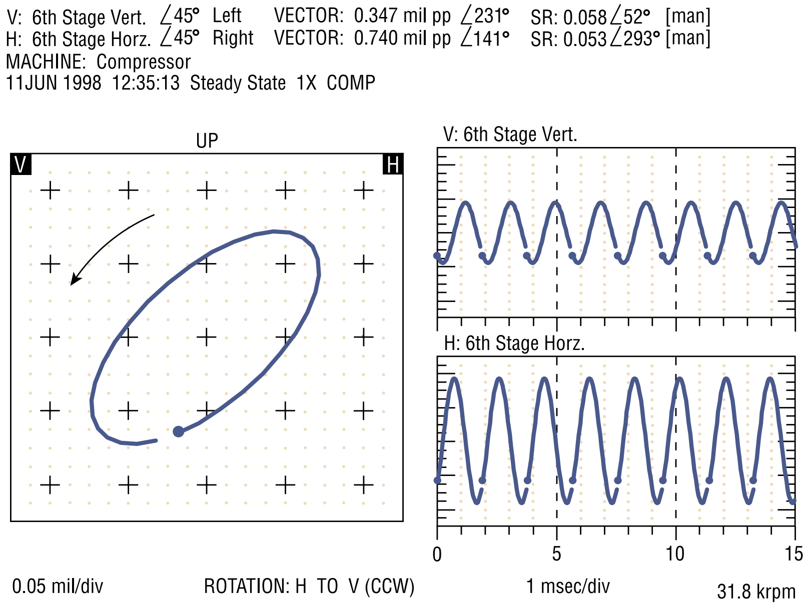

Figure 1. Customer's 1X, compensated orbit/timebase plot @ 31,800 rpm.

A Your orbit plot (Figure 2) shows the 1X, uncompensated orbit/timebase plot generated for the vertical and horizontal probe pair. Vibration in the vertical direction is 0.290 mil (7.37 µm) pp at 231°, and 0.694 mil (17.6 µm) pp at 143° for the horizontal. Measuring the major and minor axes from the 1X orbit plot yields 0.695 mil (17.6 µm) and 0.295 mil (7.49 µm), respectively. Contrast this to the full spectrum plot for the same probe pair (Figure 3), which shows a forward 1X amplitude of 0.306 mil (7.77 µm) pp and reverse 1X amplitude of 0.126 mil (3.20 µm) pp; the major and minor axes are calculated as 0.432 mil (11.0 µm) and 0.180 mil (4.57 µm), respectively. So, why is there a difference?

There are several possible reasons for the discrepancy:

1. **The amplitude accuracy of filtered orbits is affected by the settling time of the filters**. The 1X orbits in ADRE for Windows are synthesized (mathematically constructed) using the X and Y probe 1X vectors. So, the value of these vectors depends upon the length of time the vector filter has had to settle and how much the machine vibration state has changed during this settling process. The final value of the vector will depend on the filter band-

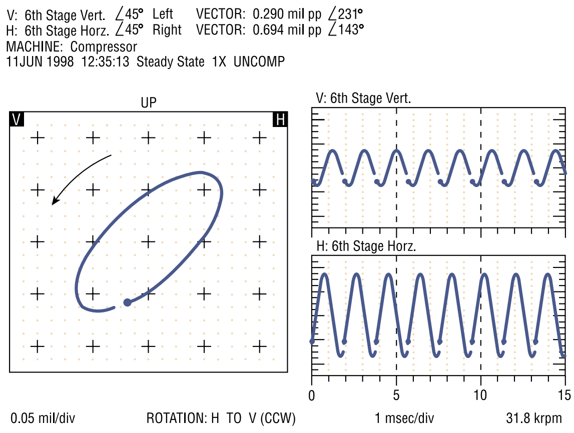

Figure 2. Customer's 1X, uncompensated orbit/timebase plot @ 31,800 rpm.

width (12 rpm versus 120 rpm) used and the rate of change of the vibration signal. If the machine vibration is changing rapidly, filter settling time can cause a significant error, especially the 12 rpm filter.

2. Waveform (orbit/timebase and spectrum) data and vector data are independent (not from the same database) and not necessarily sampled at the same time. For each set of waveform data, there are up to 10 sets of vector data. Orbit/timebase data is sampled synchronously at a rate determined by the maximum rpm set in the Keyphasor® configuration. Spectrum data is sampled asynchronously at a rate determined by the frequency span, with resolution inversely related to span. The machine vibration may change during or after the waveform sample is taken, resulting in a different value than the vector data with the same time tag.

3. When spectrum data is averaged over a number of data sets (time records) in which the vibration amplitude could be changing, it will not agree with the nonaveraged spectrum. This can happen during a partial rub, for example, or on a machine that "breathes." The spectrum that is calculated is, in effect, an average property over the length of time it took to asynchronously sample the waveforms. Some peaks during this period may be higher or lower than others during the same sample.

4. Amplitude quantization errors are large when large full scale values are used for measuring small signal levels. The 1X amplitudes are very low (less than 1.0 mil pp). At these levels, when the maximum transducer full-scale setting is used, there can be significant quantization errors in the displayed values. This is an effect of the resolution of the A/D converter. The full scale ranges should be selected to maximize resolution for the vibration amplitudes observed or anticipated.

5. Windowing functions tend to introduce greater or lesser amplitude and frequency errors in an attempt to minimize leakage. Your full spectrum plot (Figure 3) was generated using no window function. The Hanning window function is recommended as the best compromise, to reduce waveform sampling inaccuracies and correct leakage of the frequency domain peaks in the full spectrum plot FFT.

6. Slow-roll compensation and waveform compensation are not performed on half spectrum or full spectrum plots. Slow-roll compensation is only performed on the 1X filtered data. It is done by subtracting a slow-roll vector (amplitude and phase) from an at-speed vector for 1X runout correction of the orbit or timebase plot. Waveform compensation is performed on the direct (unfiltered) time domain data, which is

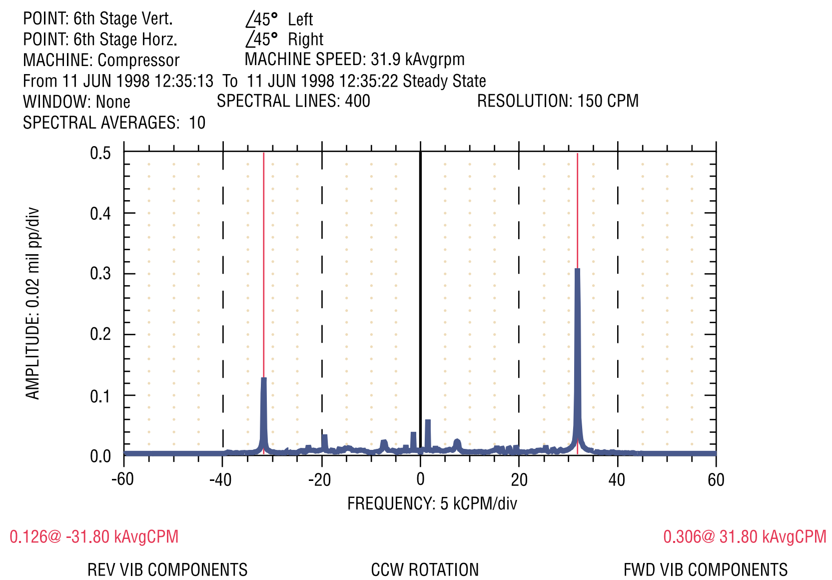

Figure 3. Customer's full spectrum plot @ 31,800 rpm (no window applied, averaged).

synchronously sampled.

Summary

Since we had access to your ADRE data file, we were able to plot a full spectrum of your data, using a Hanning window and no averaging (Figure 4). It yields major and minor axes of 0.653 mil (16.6 µm) and 0.271 mil (6.88 µm), respectively. These values are much more consistent with those from the uncompensated orbit plot (Figure 2).

This consistency should increase your confidence level in the accuracy of the data. The steps we took to generate similar data for comparison (apples to apples) illustrates the need to understand the variables that affect data accuracy: how and when your data is sampled and processed, rate of change of machine speed and signal amplitude, and filter settling times.

What frequencies are you interested in? The frequency span should be set accordingly. The frequency span for the captured data was set at 1000 Hz, and the machine runs at 31,800 rpm (530 Hz). Thus, the frequency span represented in the plots is 1.89X. The best spectral resolution is achieved when the maximum number of lines is used (400) along with the smallest possible span setting that will contain the data you are interested in, consistent with the operating conditions of your machine. For example, if you were interested in subsynchronous behavior up to 1X, a span that barely includes 1X would be the best choice. Remember that wider spans, with the same number of samples, will not increase accuracy and will reduce resolution.

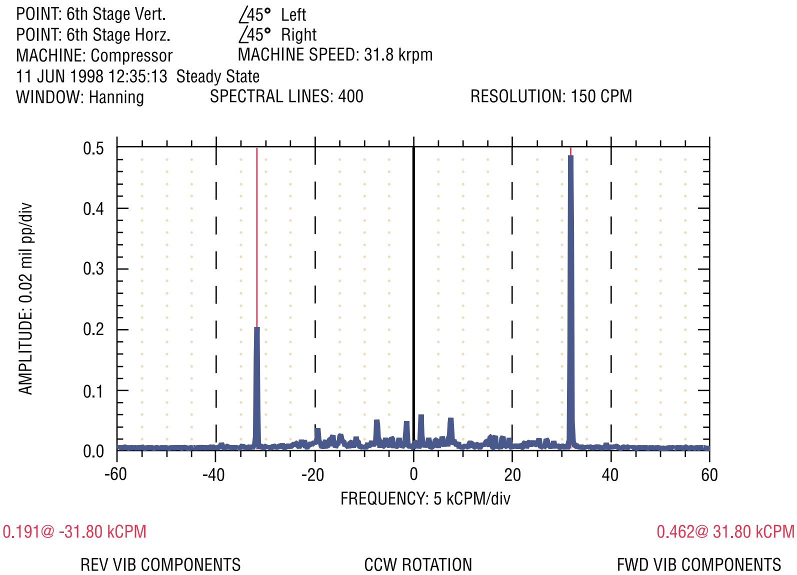

Figure 4. Customer's full spectrum plot @ 31,800 rpm (Hanning window applied no averaging).

ADRE for Windows® USER TIP:

For best full spectrum results and accuracy, choose:

- Hanning Window Function in the Spectrum Plot Control setting.
- Frequency Span in the Spectrum Sample Configuration setting which will be the smallest for the data of interest, with 400 spectral lines, for steady state data acquisition. For transient data acquisition, the faster the acceleration or deceleration rate of the machine, the fewer the number of lines should be selected. (See "3200 line spectrum ... when shouldn't you use it?" pp. 16 to 18, Orbit, June 1998.).
- Full Scale Range in the Transducer Configuration setting which will be the smallest for the amplitude value observed or anticipated.